Practical Power in the Field - Fuel Cells by Protonex

Paul Osenar, Ph.D. – CTO

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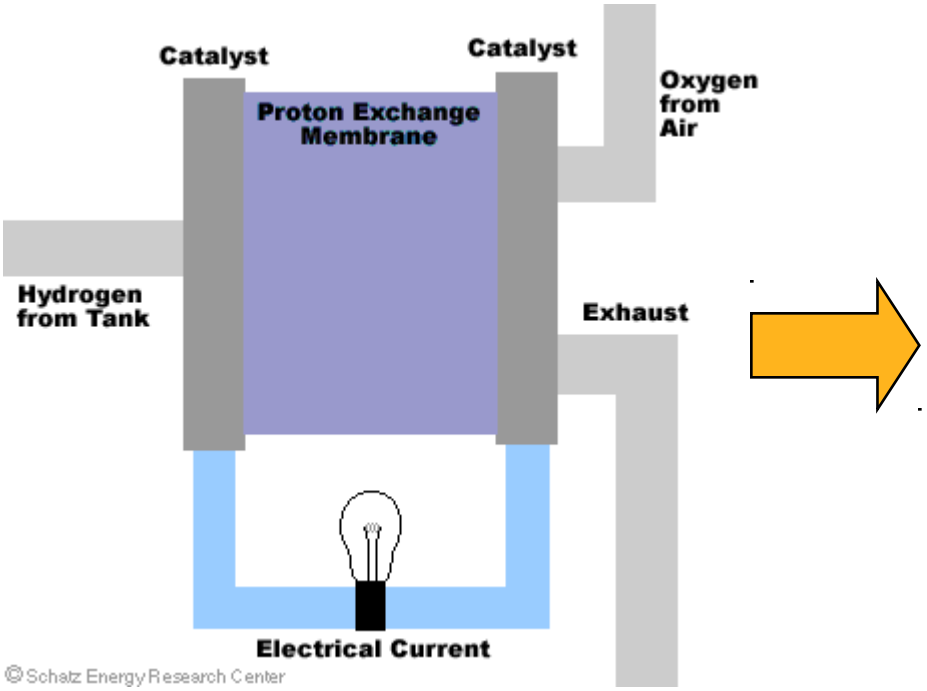
Protonex Facts

- Inspired to move fuel cells out of labs and into real products
- Design for cost and manufacturability

- **High-performance, portable power (10 – 500 Watts)**

- Delivering power with superior metrics and low cost

Fuel Cells - Function & Value Points



Anode: $H_2 \rightarrow 2H^+ + 2e^-$

Cathode: $1/2\ O_2 + 2H^+ + 2e^- \rightarrow H_2O$

Net: $H_2 + 1/2\ O_2 \rightarrow H_2O$

Fuel Cell Value Points:

- **Reduced weight**
- **Extended run times**
- **Reduced size**
- **Lower cost of ownership**

- Greater efficiency
- Reduced emissions
- Low noise level
- Lower heat signatures

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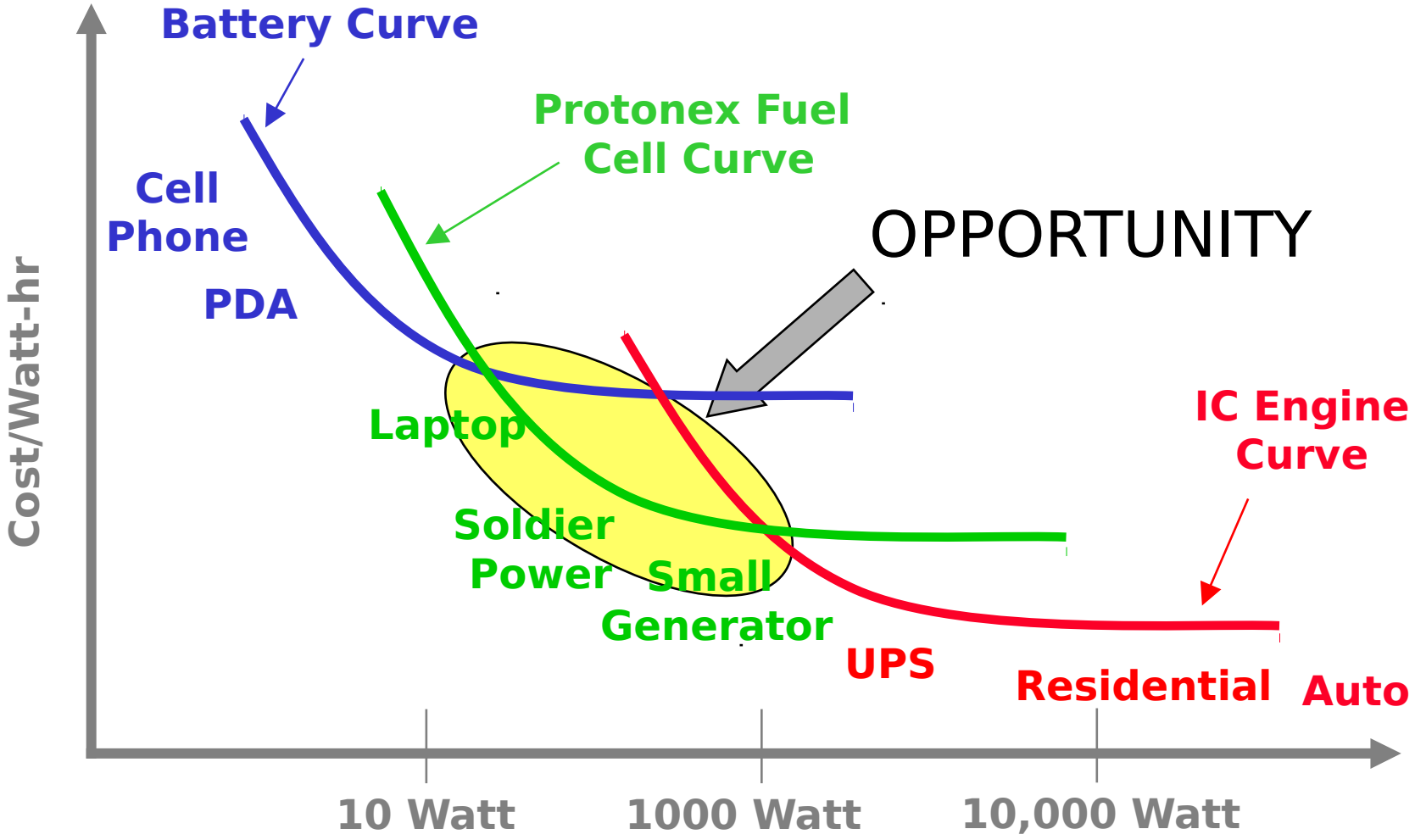
Power Range Opportunity



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Military Applications (<1kw)

- 10-100W
  - Soldier power
  - Laser range finders
  - Portable medical devices
  - Remote sensing & surveillance
  - Electronic warfare
- 100-500W
  - Field battery charger
  - Small unmanned air vehicles (UAVs)
  - Mobile robotics
  - Forward area generators

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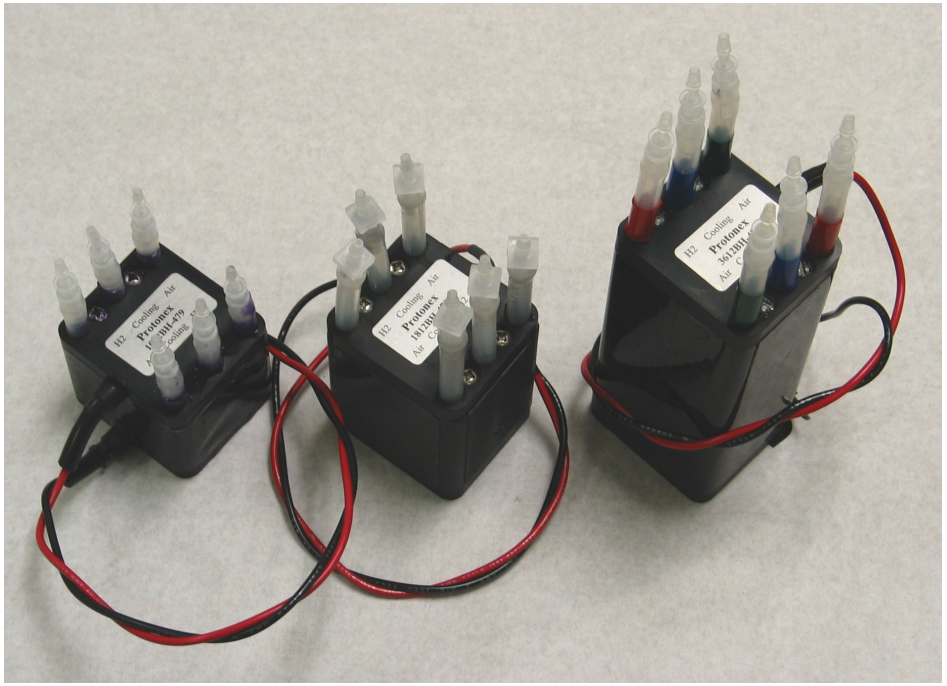
Protonex Stacks = Best in Class



3000 Series Family 50-200 Watts

- H_2 PEM technology
- Compact
- Lightweight
- Low Cost
- Robust
- Reliable
- Injection Moldable
- Multiple Patents Pending

Replaces precision components and labor intensive assembly with a simple "one-shot" moldable design resulting in very low costs, high yields, high reliability, and superior performance metrics.

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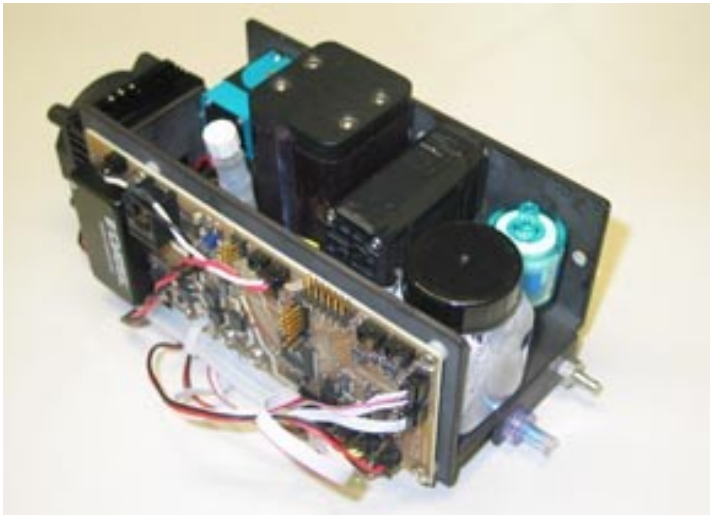
State-of-the-Art Systems

Fuel Cell Power Systems:

- Fuel cell stack
- Balance of plant
  - air, cooling, controls
- Fuel subsystem



Insides of 30 Watt System

Protonex systems are:

- Small & lightweight
- Efficient and reliable
- Manufacturable
- Easy to embed in applications

150, 500 Watt
Prototype Systems

~10” high

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Fuel for Portable Power Systems

- H_2PEM fuel cells optimal for 10 – 500 Watt portable:
  - Wide operating temperature
  - Lightweight, robust
  - Mature components / good cost profiles

- Fuel solutions provide hydrogen as needed (i.e. small volume stored)
  - 10 – 100W: Chemical Hydrides
  - 100 – 500W: Chemical Hydrides or Methanol Reformer

- Protonex co-develops fuel systems and cartridges specifically for applications

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Air Force DUST Program

Protonex NGen™ System

+

Millennium Cell – Hydrogen on Demand™

- Sodium borohydride ($NaBH_4$)

- **> 450 Whr/kg** initial fielding target
- 900 Whr/kg potential (with water recovery)
- 30 Watts, 72 hour mission

$$\mathbf{NaBH_4\ (aq) + 2\ H_2O\ (l) \xrightarrow[\text{Cat.}]{} NaBO_2\ (aq) + 4\ H_2\ (g) + heat}$$

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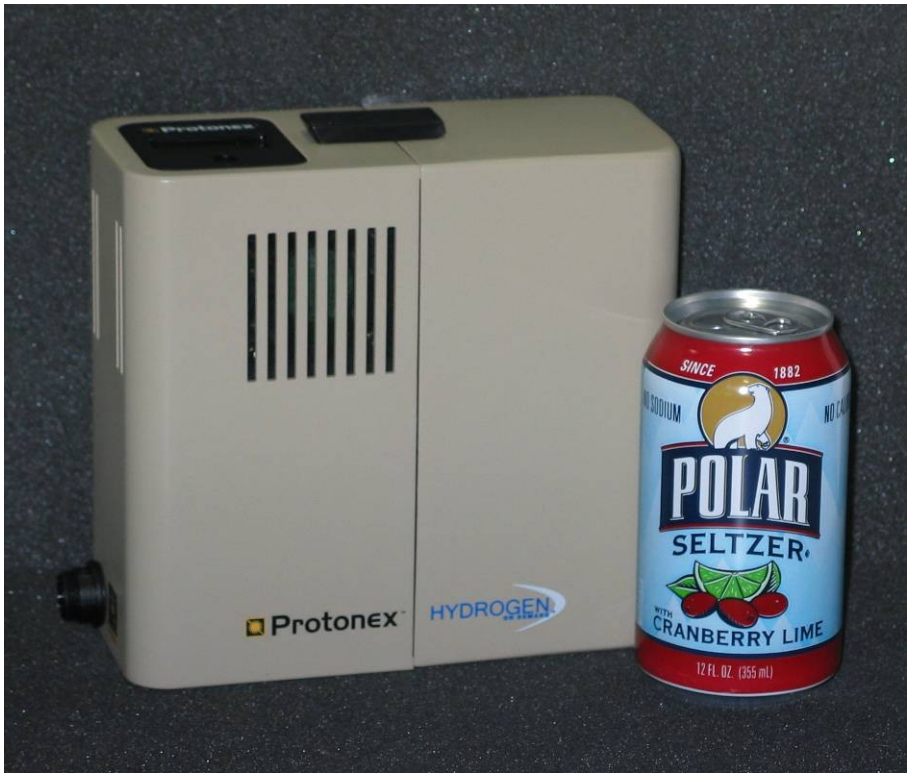
DUST Prototype One



Integrated chemical hydride fuel cell system

(full unit – 3” x 6.25” x 6.5”)

300+ Whr/kg for 72 hour, 30 Watt mission

(550+ Whr/kg with water from the field)

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Energy Density Comparison

Power Source	W-hr/kg
Lithium Primary (BA5590)	175
Lithium Rechargeable	100-190
Zn-Air (BA8180) – limited current	300-350
Protonex w/ Chemical Hydride*	**450-900**

*Based on a 30 Watt, 72 hour mission

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Man Portable Battery Comparison

Based on a 30 Watt 72 hour mission	30W Protonex Fuel Cell System	BA5590 Batteries (used today)
Solution required to meet need	1 fuel cell system 6 fuel cartridges	13 battery packs
Size of system/ consumables	4.3 Liters	11.2 Liters
Weight of system/ consumables	3.6 kg (7.9 lbs)	13.3 kg (29.3 lbs)
Total cost per mission	$433	$1,040

* Power system + fuel system and fuel included

** System amortized over 30 missions (~2000 hours)

Savings: 60% on cost **62%** on size **73%** of weight

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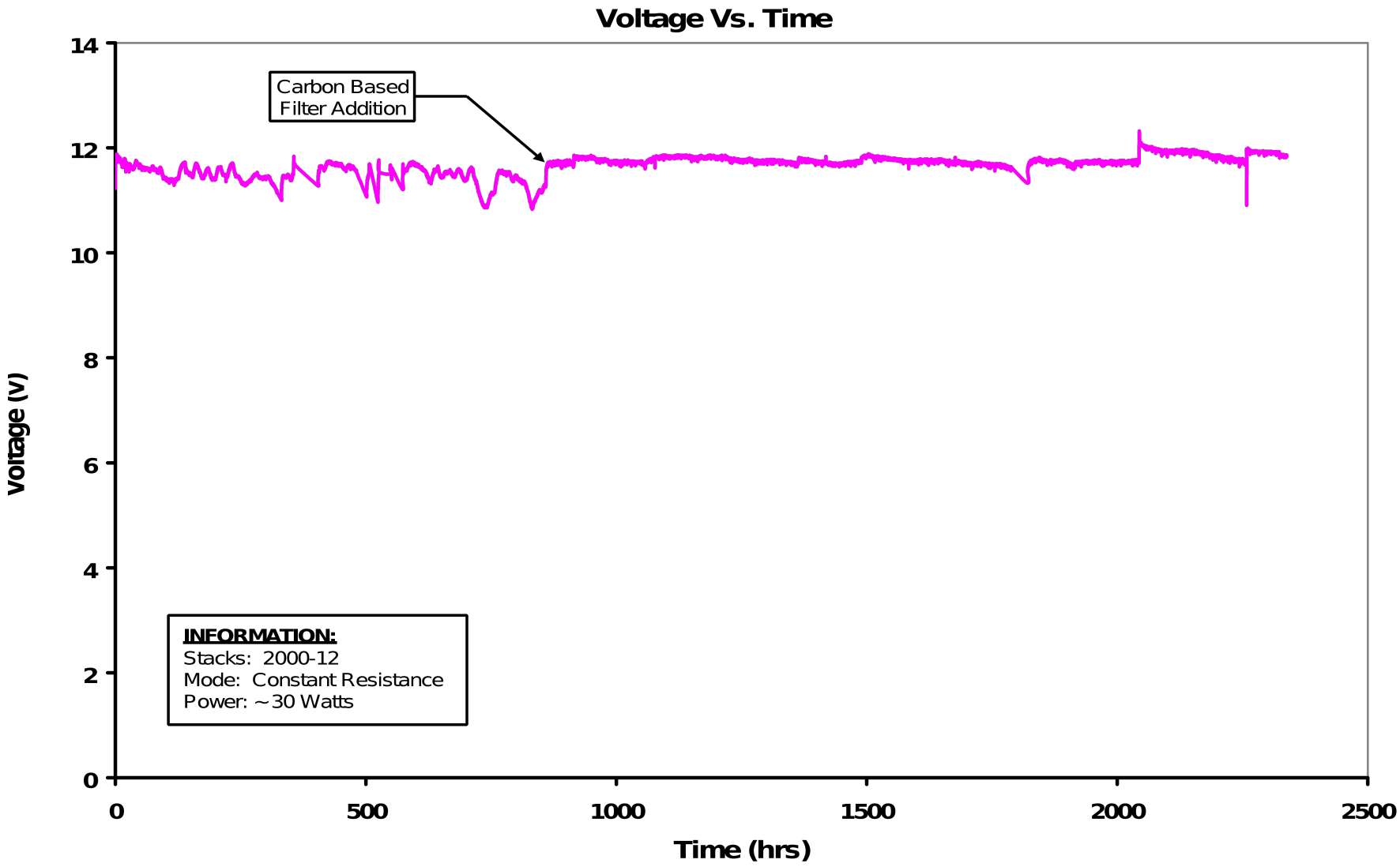
Stack Life Test >>2000hrs



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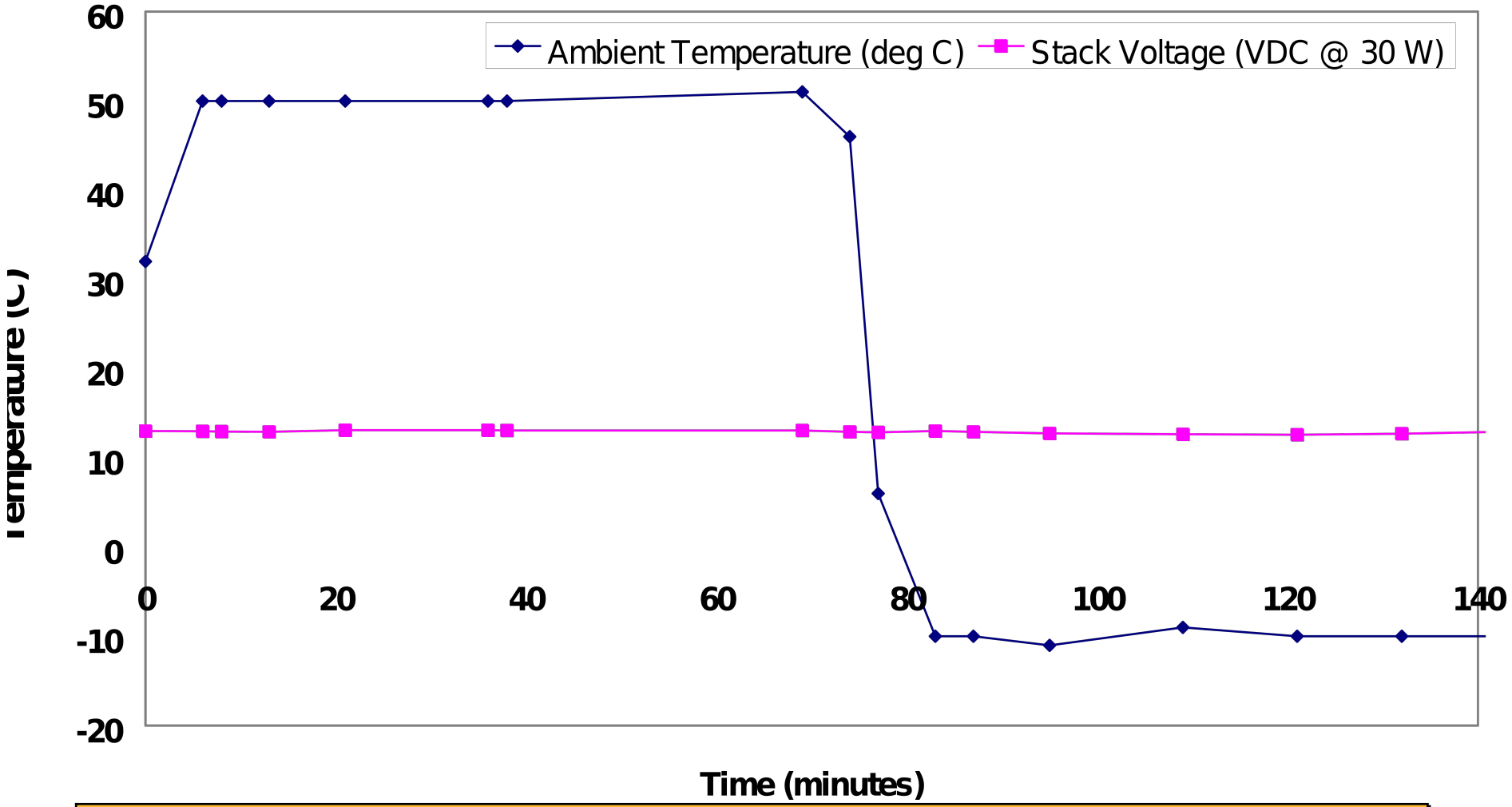
Temperature Range



Fuel cell system demonstrated -10 to 50°C to date

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Fielding Strategy

- Demonstrate reliability, operational window
- Identify / develop specific applications
- Drive down costs
  - Balance of plant development with Parker Hannifin (announced 11/04)
- Work with military primes
- Work with customer to solve power problems

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Private / Public Funding

- Private Funding Round
  - Conduit Ventures, SAS Investors, Solstice Capital and Commons Capital
- Army Research Office (TPOC - Dr. Dick Paur)
  - SBIR program for next generation sub-kilowatt stacks
- Air Force Research Lab (TPOC - Dr. Thom Reitz)
  - Dual Use Science & Technology
  - Man portable system using chemical hydride fuel
- Army Research Lab – (TPOC - Dr. Deryn Chu)
  - Development program for advanced DMFC stacks

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The Protonex Advantage

- Leading product metrics (10-500 Watt)
- Compact & lightweight
- Durable design
- Strong customer focus
- Full power solutions
- Strong military activity & support

"Powered by Protonex"

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For More Information

Greg Cipriano
VP, Marketing & Military Development
greg.cipriano@protonex.com x208

Paul Osenar
Chief Technology Officer
paul.osenar@protonex.com

Protonex Technology Corporation
153 Northboro Road
Southborough, MA 01772
508-490-9960

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